Research Areas in Computer Communication

by

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The editor of this review recently made the mistake of inviting me to discuss those problems and areas which I think require "urgent" investigation in the field of Computer Communications. What a wonderful opportunity to express my biased opinions!

First let me say that this is a most exciting time to be conducting research in the field of Computer Communications. The area has certainly come of age, the applications have clearly been identified, the technology exists to satisfy those needs and the public may even be ready for the revolution.

Perhaps the most sophisticated form of Computer Communications may be found in data communication networks. In the April 1974 issue of this review, Wushow Chou (CHOU 74) discussed some of the design problems for these networks and the reader is referred to his comments for some specific problem areas. The 1960s was the era of time-shared computing systems and other forms of multi-access computing. Computer communication networks represent multi-access in spades! These networks and computer systems give rise to inherent sources of conflict among the multiusers in attempting to access the many resources offered. The question of conflict resolution lies at the root of most of the problems that we encounter. However, we are willing to put up with the conflicts in order to gain the great benefits possible through resource sharing. Resource sharing and resource allocation are perhaps the key elements and key problems in the area of Computer Communication Systems. A fair amount of sophistication is usually required in the allocation of resources in order to realize the large savings from resource sharing. It therefore behooves one to understand the nature of these processes. Specifically, sharing will only work if the load does not exceed the capacity of the system and, in that case, large shared systems will permit efficient scheduling due to the smoothing effect of the law of large numbers. Thus in a real sense we find ourselves in the situation of deterministic processes which may be properly scheduled for ease of sharing.

Some of the specific problem areas in which research is currently taking place and where principal results are still required include the following. First there is the design of large computer communication networks; by this I mean on the order of a thousand nodes or more. The computational and combinatorial complexities encountered here are enormous and some extremely clever partitioning and decomposition techniques are required for efficient design. Certainly not all the design problems have been resolved for the moderate sized networks such as, for example, the ARPANET (CARR 70, CROC 72, FRAN 70, FRAN 72, HEAR 70, KLEI 70, MCKE 72, MCQU 72, ORNS 72, ROBE 70,

ROBE 72, ROBE 73a, THOM 72). Among the more serious technical problems remaining in moderate size network design is the flow control problem which has been a constant boobie trap in existing networks. Flow control refers to those procedures which limit the entry of messages into the network for one reason or another. These control procedures incorporate reassembly functions and/or sequencing functions which can lead to deadlock conditions or throughput degradation conditions. Clever and effective flow control procedures along with a procedure for verifying their capability and correctness is an open research area. Another class of problems which are of current research importance involve the use of radio for communications. In particular, satellite communications in a computer communications network offers some extreme advantages with regard to providing long-haul high speed inexpensive communications. These satellite channels have been studied in a multi-access uplink, broadcast downlink mode and have been shown to be quite effective in this role (ABRA 73, KLEI 73, ROBE 73b). The characteristic of satellite communications is that the propagation delay usually far exceeds the transmission time of a packet or message. Numerous transmission techniques are possible and one can take advantage of the broadband capabilities of the satellite. At the other extreme, the use of ground radio transmission, once again in a multiaccess broadcast mode, is extremely interesting for providing access from a terminal to a switching computer acting perhaps as a gateway into a network. The problems here are similar to that of satellite transmission except that the parameters yield a propagation delay which is far less than the transmission time for the packet or message. As a result, special techniques are used to take advantage of this relationship (KLEI 74a). Another extremely interesting class of problems, which as yet has not been properly studied, is that of interconnecting different computer networks on a national or global basis. Just what the protocols should be and where these protocols should reside are as yet unsettled. For example, should the assembly be done at the gateways between networks or at the source and destination of the message traffic? Further, how can one sensibly handle the case when different sized packets are expected in each of the networks? More, how does one introduce an equitable charging and accounting scheme in such a mixed network system? In fact, the general question of accounting, privacy, security and resource control and allocation are really unsolved questions which require a sophisticated set of tools.

In all of these research endeavors, it is worthwhile to indicate that set of tools in which the research scientist should be skilled. Among these I would emphasize probability theory (FELL 66), queueing theory (KLEI 74b), network flow theory (FRAN 71), and optimization theory (BEVE 70). In addition, it is almost imperative that the researcher have a strong computer science background with an emphasis perhaps in operating systems, and this should be supplemented with some background in communication theory, at least at the elementary levels. Such individuals tend to be rare with the weakness either coming on the theoretical side or on the computer science background side. At the universities we are attempting to correct this lack and are meeting with partial success.

Above I have outlined some of the outstanding problems which require solution in terms of impact their solutions will have on the growth of computer

communications. By design I have been vague in order not to bias the outlook which comes from fresh entries into this field. The problems certainly are significant and challenging and are worthy of one's attention. However, I would also urge the neophyte researcher to be on the lookout for additional applications of the so far successful techniques which we have used in computer communications, and attempt to find their use in areas outside this field.

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